Power System Restoration With Transient Stability

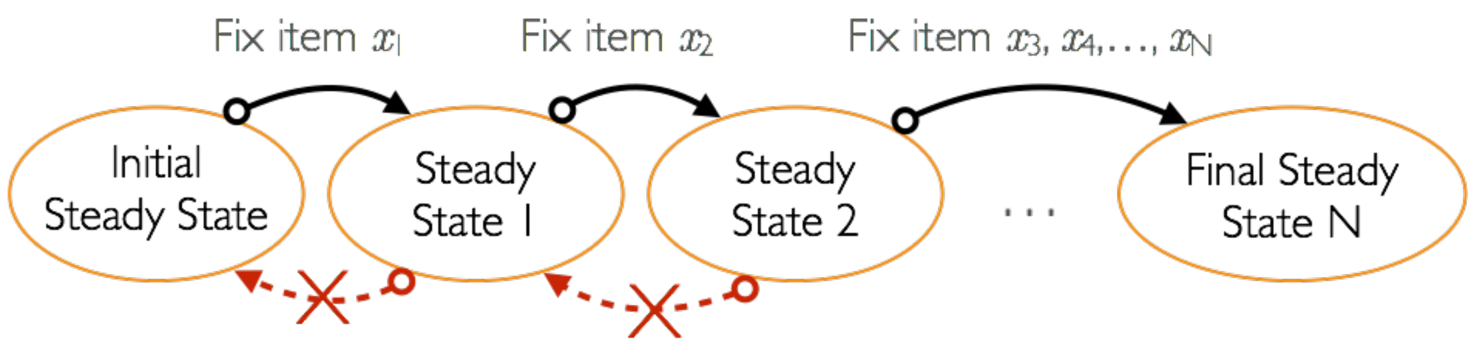
Terrence W.K. Mak, Hassan Hijazi, and Pascal Van Hentenryck

Power System Restoration

- Why? Natural disasters, infrastructure ageing, operator errors …
- Outcome: A city could be in a total blackout

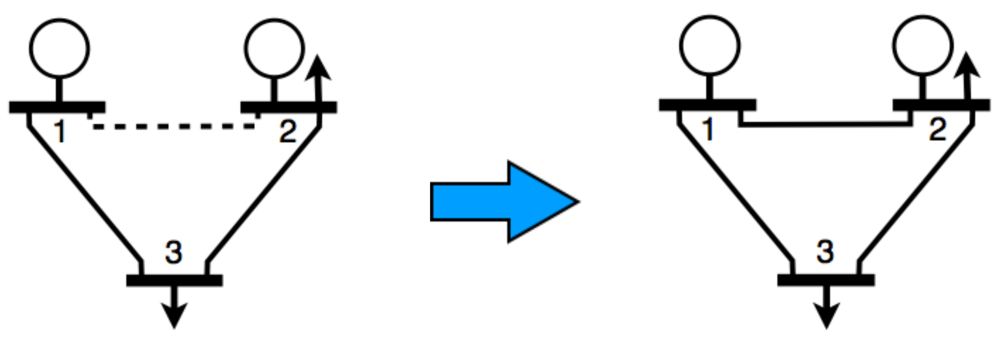
Restoration Ordering Problem

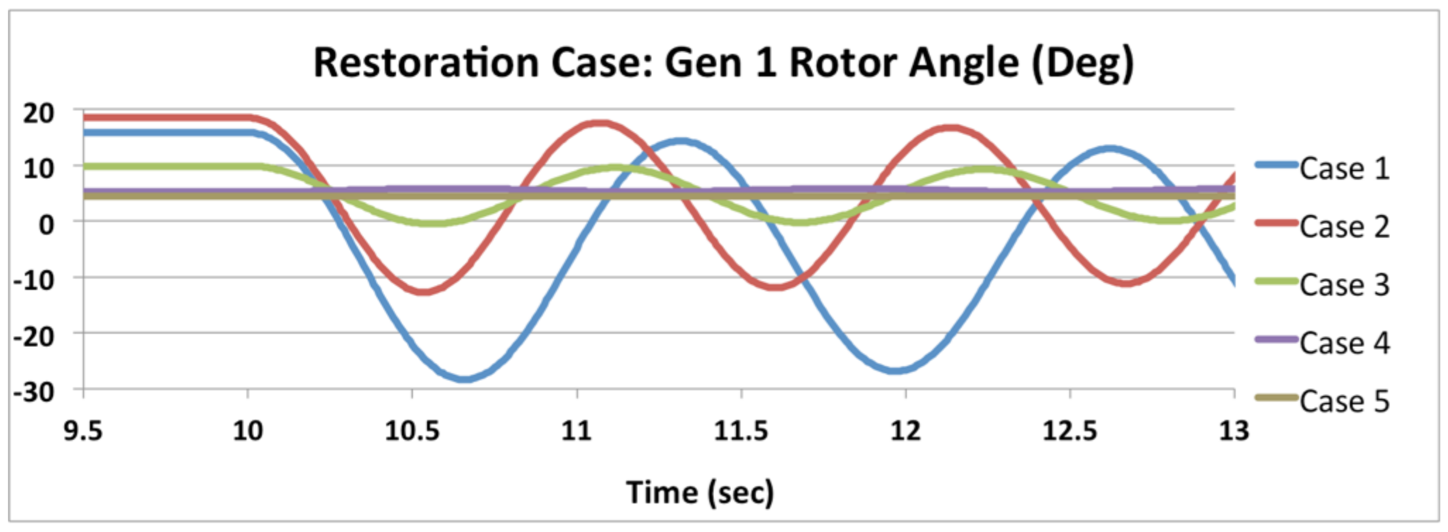
- Goal: Compute the best restoration ordering [x_1, x_2, x_3, …, x_N] of damaged items such that loads could be brought up as quickly as possible [PSCC'11]



Transient Stability Assumption

- Assumption: Traversing from one steady state to the other must always be feasible
- What we know: Different generator dispatches will have different rotor stability [PSCC'14]

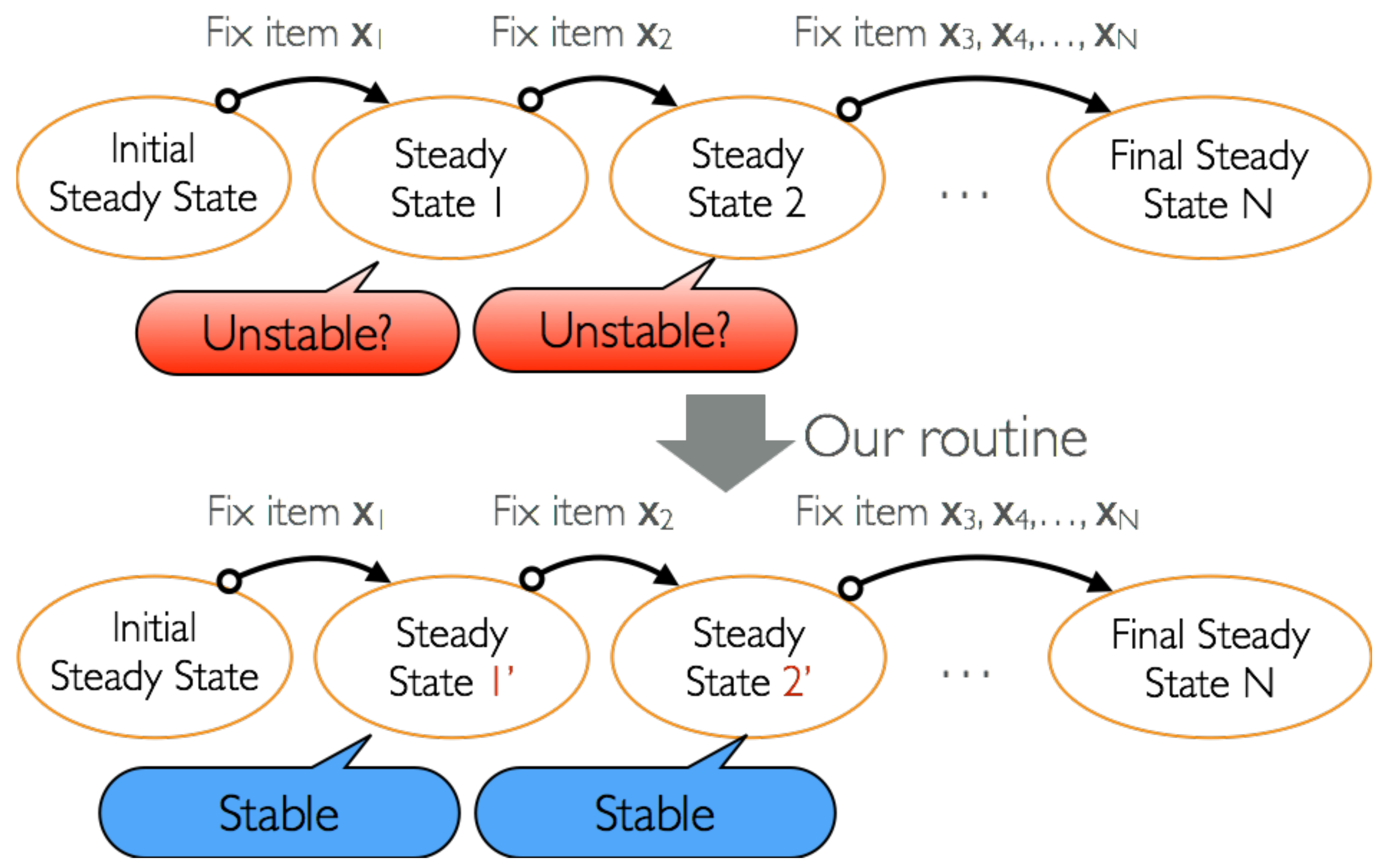


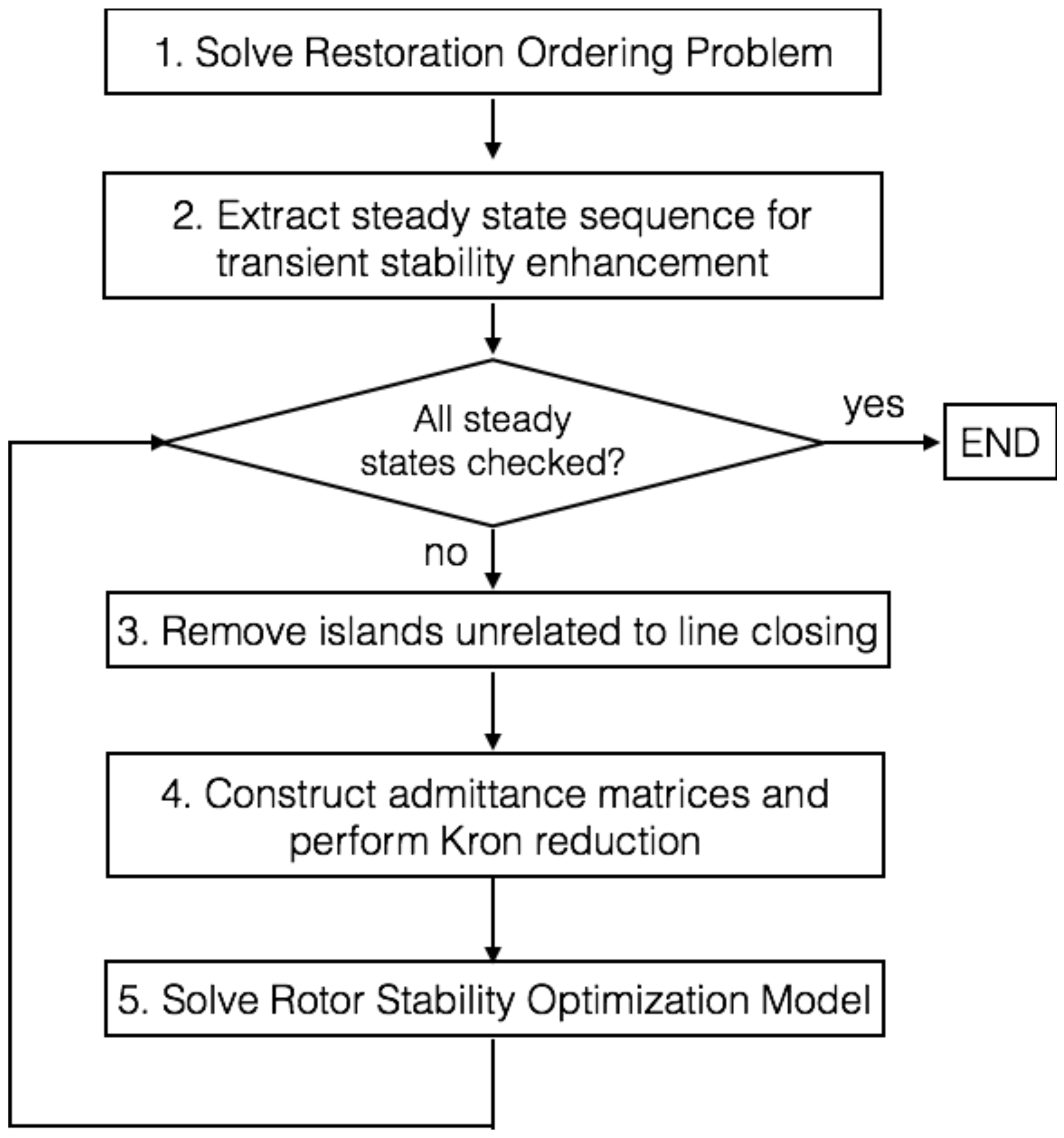


Case	Bus 1	Bus 2	Bus 1	Bus 2	Gen 1 Pow.	Gen 2 Pow.	1st Swing
	Volt. (kV)	Volt. (kV)	Ang. (deg)	Ang. (deg)	(MW/Mvar)	(MW/Mvar)	(deg)
1	146.28	97.24	0.00	-47.58	221.12/143.46	20.00/18.00	44.229
2	146.28	146.28	0.00	-35.33	207.42/28.05	20.00/78.32	31.249
3	146.28	141.725	0	-12.14	102.59/10.66	102.59/10.66	10.385
4	146.28	123.84	0.00	0.00	61.05/48.08	143.85/-30.00	0.619
5	146.28	146.28	0.00	0.00	45.37/6.10	157.31/3.16	0.002

Stability Enhancement Routine

- Research goal: Given a restoration order, can we guarantee rotor stability?





- Challenge: Rotor swings are governed by 1st order differential equations.
- We design a non-linear model including generator dispatches to minimize the rotor swings [AAAI'15]

Experimental Results

- Study: whether the steady states returned by the ROP are transient-stable
- Measure: Minimum change in generator dispatches to ensure transient stability
- Benchmarks: 6, 14, 30, 39, 57 bus from MATPOWER
- Implementation: AMPL with IPOPT 3.11

	6 Bus				14 Bus				30 Bus			
	Maximum Rotor Swing				Maximum Rotor Swing				Maximum Rotor Swing			
Gen. Reactance	90	40	10	1	90	40	10	1	90	40	10	1
0.02	0.00002	0.00002	0.00002	0.17967	0.00000	0.00000	0.00000	6.53902	0.00004	0.00003	0.00004	2.91547
0.06	0.00003	0.00003	0.00003	0.10593	0.00000	0.00000	0.00000	8.67193	0.00004	0.00003	0.00004	3.07084
0.10	0.00003	0.00002	0.00002	0.00843	0.00000	0.00000	0.00000	8.18311	0.00004	0.00004	0.00004	3.76922
0.14	0.00002	0.00003	0.00002	0.30335	0.00000	0.00000	0.00000	6.09923 (1)	0.00004	0.00005	0.00004	4.17696
0.20	0.00003	0.00003	0.00003	1.01248	0.00000	0.00000	0.00000	3.66457 (3)	0.00004	0.00004	0.00004	4.07680

	39 Bus				57 Bus			
	Maximum Rotor Swing				Maximum Rotor Swing			
Gen. Reactance	90	40	10	1	90	40	10	1
0.02	0.00001	0.00001	20.52951	7.95879 (6)	0.00000	0.00000	0.66260	131.39311
0.06	0.00001	0.00001	81.80927 (1)	0.00002 (7)	0.00000	0.00000	1.36766	1.12417 (21)
0.10	0.42052	0.28436 (1)	78.24781	48.13747 (5)	0.23766	0.23766	39.33088	1.14312 (21)
0.14	0.49691	0.49698	60.35684	41.99449 (5)	0.68299	0.67222 (1)	73.84672	1.26118 (21)
0.20	0.00002	0.00002	34.26957	69.35875 (3)	0.83704	0.83744	120.01411 (1)	1.41655 (21)